



CULTURES OF UREDINEÆ IN 1899.<sup>1</sup>

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WITH the exception of the very important results achieved by Thaxter in the study of American Gymnosporangia, together with similar work by Farlow, Halsted, Stewart, and Carver, only a few attempts have been made in America to trace the connection experimentally between the forms of the Uredineæ.

The three stages of the clover rust (*Uromyces Trifolii*) were shown by Howell to be genetically connected and the two forms of the raspberry rust (*Gymnoconia interstitialis*) by Clinton. A slight amount of work in this line of research, chiefly of a confirmatory character, was carried out between 1889 and 1898 by Bolley, Stuart, and the writer. The yet unpublished results of Carleton, obtained as part of the work of the division of vegetable physiology and pathology at Washington,<sup>2</sup> complete the mention of all American efforts in this line that now occur to the writer.

The cultures made during the present season (1899), herein to be described, were conducted, with the exception of a single trial, under glass in the greenhouses of the Experiment Station at Purdue University, and upon plants in pots, the plants remaining under cover until the observations were completed. Material bearing teleutospores of a number of species was collected during the previous autumn and winter and preserved until needed by tying in loose muslin and placing on the ground out of doors.

The method generally adopted to secure infection was the same, whether æcidia, uredo, or teleutospores were in hand. The potted plant was first wet with an atomizer, parts covered with a bloom being rubbed with the fingers until the water

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<sup>2</sup> Issued as Bulletin No. 16 since the paper was read.

adhered. The spores were scraped from the host material with a knife blade and placed on definite areas of the plant to be infected, the parts marked by bits of string, and a bell jar placed over the whole plant. After a day or two the bell jar was removed. With most species, if the operation had been successful, the results began to appear in six to fourteen days.

In order that the simple procedure here outlined may uniformly give information that can be relied upon, many small precautions must be observed that cannot now be spoken of. In every case it is wise to first make a drop culture, to be sure that the spores are viable.

In the following outline of the work accomplished it is impossible to go into much detail, or mention all the items of interest that are naturally brought to mind. It is also impossible to adjust the nomenclature in accordance with the new knowledge which the cultures have furnished.

#### 1. PUCCINIA PHRAGMITIS (*Schum.*) *Körn.*

The host of this species, *Phragmites communis*, does not grow in the vicinity of Lafayette, Indiana, where the work was done, and I am indebted to Dr. J. J. Davis of Racine, Wis., and Professor C. E. Bessey, of Lincoln, Neb., for teleutosporic material. Abundance of æcidia were obtained by sowing the teleutospores upon *Rumex crispus* and *R. obtusifolius*, thus confirming the results obtained by European investigators. The dates are as follows:

May 2, Teleutospores (Wis.) sown on *Rumex crispus*; May 12 spermogonia; May 15, æcidia.

May 4, Teleutospores (Wis.) sown on *Rumex obtusifolius*; May 15, spermogonia; May 16, æcidia.

May 9, Teleutospores (Neb.) sown on *Rumex crispus*; May 15, spermogonia; May —, æcidia.

May 9, Teleutospores (Neb.) sown on *Rumex obtusifolius*; May 15, spermogonia; May —, æcidia.

The preliminary drop cultures showed the most vigorous germination of teleutospores obtained with any species, and far surpassing most of those under observation. The sowings also

produced a wealth of æcidia. From these facts one would infer that æcidia on *Rumex* should be common, for the teleutospore condition occurs throughout the United States. Yet I am not aware of a single authentic record of *Æcidium rubellum* being found in North America. To be sure, it occurs in the earliest published list of American fungi by Schweinitz, who was a notably accurate observer. But his remark that the spots were usually sterile, makes it fairly certain that what he collected were not æcidia, but the spots made by *fungi imperfecti*. Both Professor Bessey and Dr. Davis at my suggestion made repeated and thorough search about the places where the teleutospores were found in their localities, but saw no æcidia. Improbable as it may seem, there yet appears to be no explanation of the remarkable vigor of this heteroecismal species, but to suppose that the æcidia do occur in America, and that, so far, they have been overlooked.

#### 2. PUCCINIA CONVULVULI *Cast.*

The teleutospores of this very common species of rust on *Convolvulus sepium* were sown on the host, before the weather permitted it to start out of doors, and were duly followed by a rich development of spermogonia and subsequently of æcidia. It was thus experimentally shown to be an autoecious species, as has always been tacitly accepted. The dates are as follows: May 8, Teleutospores sown; May 16, spermogonia; June 6, æcidia.

#### 3. PUCCINIA CARICIS (*Schum.*) *Reb.*

The æcidiospores from *Æcidium Urticæ* were sown May 17 on the young leaves of *Carex stricta* and in eleven days were followed by uredospores. A sowing at the same date on *Carex cephalophora* gave no infection. This shows that *Carex stricta* is a host for *Puccinia caricis*, but there is reason to believe that it also acts as a host for other species of Puccinia. The American rusts on *Carex* are yet little understood.

#### 4. UROMYCES EUPHORBIAE *C. & P.*

There has been an almost uniform opinion among American botanists that the *Æcidium* occurring abundantly upon many



species of *Euphorbia* is not genetically related to the brown rust equally abundant upon the same hosts. The evidence I have to offer is not conclusive, but, so far as it goes, must change this view. On June 20 æcidiospores from *Euphorbia nutans* were sown upon two plants of the same species and upon one plant of *Euphorbia maculata*. Nine days afterward uredo appeared upon one of the plants of *Euphorbia nutans*, and in eleven days upon the other, followed in both cases by teleutospores after a time, the exact date not recorded, but the plant of *E. maculata* showed no infection.

Instead of speculating upon such meager data, I am inclined to believe that *Uromyces Euphorbiæ* is an autoecious species, and to await further cultures showing if it is separable into races.

#### 5. PHRAGMIDIUM SPECIOSUM Fr.

The intimate association of a cæoma, which is not distinguishable from *Cæoma miniata* Schl., with this exclusively American species of *Phragmidium*, would have been accepted as sufficient evidence of its genetic connection, if the same form apparently had not been considered in Europe as the first stage of the very different *Phragmidium mucronatum*, a species that is also common in this country.

At the time when the teleutospores of *Phr. speciosum* were in germinating condition no potted plants of native roses were available, and sowings were made upon the leaves of a tea rose, the Kaiserin Augusta Victoria. The work was done by my assistant, Mr. William Stuart, and the dates are not at hand, but in due course of time many pustules of cæoma appeared. These bore every resemblance to the usual form, although they did not become very large, which may have been due to the host not being congenial.

It is probably safe to assume that the rose cæoma in this country belongs wholly to *Phragmidium speciosum*, or else that there are two species not at present separable.

#### 6. TRIPHAGMIUM ULMARIAE (Schum.) Lk.

This species of rust, not heretofore reported for America, so far as the writer knows, was found in considerable abundance

this spring near Lafayette, Ind., upon *Ulmaria rubra* (*Spiræa lobata*), in the bright red cæoma stage. Feeling at first uncertain of the identity of the rust, the cæoma spores were sown upon the *Ulmaria*, and also upon *Salix*, *Convolvulus*, and *Ipomœa*, with the result that it grew only upon *Ulmaria*, producing at first uredospores and afterward teleutospores. An after-sowing of uredospores upon *Ulmaria* gave a crop of more uredospores. The dates are as follows:

May 17, Cæomospores sown on *Ulmaria rubra*; May 30, uredo; July — teleutospores.

May 17, Cæomospores sown on *Salix longifolia*; no infection.

May 23, Cæomospores sown on *Convolvulus sepium*; no infection.

May 24, Cæomospores sown on *Ipomœa pandurata*; no infection.

June 16, Uredospores sown on *Ulmaria rubra*; July —, uredospores.

#### 7. PUCCINIA AMERICANA Lagh.

This grass rust on various species of *Andropogon* is very common throughout North America, but has been generally confounded with *Puccinia Andropogi* Schw., which has the same range and affects the same hosts. The teleutospores are barely distinguishable, but the uredospores are entirely unlike those of *P. Americana*, being large and thin walled, those of *P. Andropogi* small and thick walled. The detection of the æcidium is due to the careful observation of Mr. William Stuart, who noticed that plants of *Pentstemon pubescens*, growing near *Andropogon* bearing teleutospores of the previous year, were well covered with æcidia (*Æcidium Pentstemonis* Schw.), while the same species in other localities was quite free. With this hint sowings were undertaken. Teleutospores from *Andropogon scoparius* were sown on *Pentstemon pubescens* and æcidia appeared in great abundance and vigor; æcidiospores were sown on *Andropogon* and large, thin-walled, brown uredospores appeared. The results were ample and complete, and were further emphasized by similar results subsequently obtained by Mr. Stuart. The dates are as follows:

May 3, Teleutospores from *Andropogon scoparius* sown on *Pentstemon pubescens*; May 11, spermogonia; May 20, æcidia.

May 4, Teleutospores from *A. furcatus* sown on *Oenothera biennis*; no infection.

May 15, Æcidiospores from *P. pubescens* sown on *A. scoparius*; May 29, uredo.

#### 8. PUCCINIA ANGUSTATA *Pk.*

The detection of the æcidium of this common rust on *Scirpus* was also due to a fortunate observation. It was noticed that some plants of *Lycopus*, growing within a few feet of *Scirpus atrovirens* covered with last year's teleutospores, were well besprinkled with æcidia (*Æcidium Lycopi* Ger.), while plants some distance away were free. Sowings of æcidia were made on the leaves of the *Scirpus* and characteristic uredo obtained. The hint was secured so late in the season that only one sowing was possible, but the result is thought to be measurably reliable.

May 23, Æcidiospores from *Lycopus Americanus* sown on *Scirpus atrovirens*; June 6, uredo.

#### 9. PUCCINIA WINDSORIÆ *Schw.*

This rust occurs, often in great abundance, upon the much benamed grass, *Triodia cuprea* (*Sieglingia seslerioides* Scrib.), which in the days of Schweinitz was standing in the genus *WindSORIA*. The name of the rust was applied in Burrill's *Parasitic Fungi of Illinois* fourteen years ago, to the very different rust on *Muhlenbergia*, hence great confusion has arisen, and in nearly all recent lists and treatises the name is misused:

The hint that led to successful cultures came from an observation upon proximity, as in the previous cases. A small shrub of *Ptelea trifoliata* was made conspicuous by the bright yellow spots of *Æcidium Pteleæ* B. & C., and not ten feet away was a large clump of the grass with the dead stems and leaves black with teleutospores. Successful sowings of æcidiospores were made on the grass, but the season by this time had advanced so far that germinating teleutospores were no longer obtainable with which to try the reverse cultures. The dates are as follows:

May 15, Teleutospores sown on *Ambrosia trifida*; no infection.

May 17, Teleutospores sown on *Napæa dioica*; no infection.

June 8, Æcidiospores sown on *Triodia cuprea*; June 15, uredo.

June 16, Æcidiospores sown on *Triodia cuprea*; June 23, uredo.



## 10. PUCCINIA VILFÆ A. &amp; H.

This species of rust, better known as *P. Sydowiana* Diet., is necessarily restricted in the vicinity of Lafayette to the few localities where the host, *Sporobolus longifolius*,<sup>3</sup> is to be found. My attention was called to the fact by Miss Lillian Snyder that in such localities the exceedingly common upright verbenas were richly covered with *Æcidium verbenicola* K. & S., and with no other species of æcidia in the vicinity. Going over the ground myself, I found that the verbenas, *Verbena stricta* being particularly abundant, were more thickly studded with æcidia the closer they stood to tufts of rusted *Sporobolus*, and that fifty feet away from such source of infection they would be entirely free.

Cultures were undertaken in 1898, but too late in the season to secure results. In the mean time a morphological resemblance was observed between the spores of *Æcidium verbenicola* and the uredospores of *Puccinia Vilfæ*, that gave another hint at genetic relationship. Both sorts of spores were approximately obovate, with colorless walls, greatly thickened at the apex, and papillose instead of echinulate. Successful cultures have shown that these rather uncommon characters meant more than a coincidence in this case. It is the first time, so far as the writer knows, that any significant resemblance has been pointed out between the spores of æcidia and uredo of the same species.

For some unexplained reason I was unsuccessful in germinating the teleutospores of *P. Vilfæ*, although they were taken a number of times directly from the field. But with æcidiospores the results were ample and convincing. The dates are as follows:

May 31, Æcidiospores from *Verbena stricta* on *Sporobolus longifolius*; June 10, uredo.

June 9, Æcidiospores from *Verbena stricta* on *Sporobolus longifolius*; June 21, uredo.

<sup>3</sup>Since this paper was read I have discovered that the grass under observation was *Sporobolus longifolius* (Torr.) Wood, instead of *S. asper*, as given in the manuscript, and printed in Science 10: 565, and Proc. A. A. A. S. 48: 299. The latter grass does not grow in this region.

II. PUCCINIA PERIDERMIOSPORA (*E. & T.*) *Arth.*

In studying the grass rusts it was noticed that a form on *Spartina*, well represented in American herbaria and usually called *Puccinia Phragmitis*, had uredospores similar to those of *Puccinia Vilfæ*, just described. I searched through my collection of *Æcidia* to see if any species with corresponding apically thickened spores could be found, and was rewarded in the case of *Æcidium Fraxini* Schw. With this morphological hint as the sole guide cultures were undertaken.

*Spartina* does not grow within many miles of Lafayette, and I am indebted to the kindness of Professor C. E. Bessey, of Lincoln, Neb., and Mr. H. H. Hume, of Ames, Iowa, for teleutosporic material upon *Spartina cynosuroides*. The teleutospores germinated with marked vigor, and were first sown on *Ptelea trifoliata*, the small plants obtained being mistaken for *Fraxinus*. When the mistake was discovered, and sowings were made on *Fraxinus viridis*, infections were first secured. As no small plants of *Fraxinus* were available, the spores were sown upon cut twigs placed in water in the greenhouse, and upon a low branch of a large tree out of doors. There could be no fear of spontaneous infection, as the species does not occur in the region, either upon *Spartina* or *Fraxinus*, but the usual precautions were taken. The sowings were both successful. The dates are as follows:

- May 8, Teleutospores (Neb.) sown on *Ptelea trifoliata*; no infection.
- May 9, Teleutospores (Neb.) sown on *Ptelea trifoliata*; no infection.
- May 9, Teleutospores (Iowa) sown on *Ptelea trifoliata*; no infection.
- May 15, Teleutospores (Neb.) sown on *Ptelea trifoliata*; no infection.
- May 17, Teleutospores (Iowa) sown on cut twigs of *Fraxinus viridis*; May 24, spermogonia; June 6, æcidia.
- May 17, Teleutospores (Neb.) sown on tree out of doors of *Fraxinus viridis*;
- May 29, spermogonia; June 8, æcidia.

## SUMMARY.

The following are the eleven species of Uredineæ, whose æcidial and teleutosporic forms have been definitely connected by cultures:



1. *Puccinia Convolvuli* Cast. and *Æcidium Calystegiae* Desm. with sowings of teleutospores.
2. *Puccinia Phragmitis* (Schum.) Körn. and *Æcidium rubellum* Pers. with sowings of teleutospores.
3. *Puccinia Americana* Lagh. and *Æcidium Pentstemonis* Schw. with sowings of æcidiospores and teleutospores.
4. *Puccinia Windsoræ* Schw. and *Æcidium Pteleæ* B. & C. with sowings of æcidiospores.
5. *Puccinia Vilfæ* A. & H. and *Æcidium verbenicola* K. & S. with sowings of æcidiospores.
6. *Puccinia peridermiospora* (E. & T.) Arth. and *Æcidium Fraxini* Schw. with sowings of teleutospores.
7. *Puccinia Caricis* (Schum.) Reb. and *Æcidium Urticæ* Schum. with sowings of æcidiospores.
8. *Puccinia angustata* Pk. and *Æcidium Lycopi* Ger. with sowings of æcidiospores.
9. *Uromyces Euphorbiæ* C. & P. and *Æcidium Euphorbiæ* Am. Auct. with sowings of æcidiospores.
10. *Phragmidium speciosum* Fr. and *Cæoma miniata* Am. Auct. with sowings of teleutospores.
11. *Triphragmium Ulmaræ* (Schum.) Lk. and *Cæoma Ulmaræ* Thüm. with sowings of æcidiospores and uredospores.

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